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THE ROLE OF HEAVY CHEMICALS IN INDUSTRIAL DEVELOPMENT

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AGENDA ITEM D 12.1

THE ROLE OF HEAVY CHEMICALS IN INDUSTRIAL DEVELOPMENT

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1. The spectacular growth of the heavy chemical industry since 1945 in the highly industrialised countries has naturally encouraged the inclinations of the developing nations to accord this field a major place in their programmes of industrial development. In some cases this policy is justified but before assuming that this is always so it is necessary to consider the nature, functions and fundamental economics of the industry and hence the role it should play in the industrial development of the less well-developed areas.

2. "Heavy" chemicals are difficult to define exactly in succinct terms but broadly they may be described as those chemicals produced in a tonnage sufficiently large to permit the development of highly sophisticated chemical processes and the design of specialized plants for each individual process (or at most one or two closely similar processes in campaign working.) It is not necessary to dilate on the striking growth of the sciences of chemical engineering and process technology directed specifically towards this end but it must be emphasised that the universal characteristic of modern heavy chemical industry is the high degree of "knowhow" or more euphoniously "process technology" and specialisation peculiar to each and every such process.

3. It must also be recognised at the outset that the heavy chemical industry rarely serves the public directly but that most of its products form the raw materials or essential auxiliaries of other manufacturing industries. Indeed almost all industries are dependent upon them. In countries such as Australia it is customary to refer to agriculture, grazing etc., as "primary", and manufacturing as "secondary" industries. In this concept it would not be inappropriate to describe the heavy chemical industry (with others) as "tertiary" industry. These terms refer to considerations of timing or evolution rather than of ultimate importance. It is obvious that in general it would be unwise to embark upon a programme of heavy chemical manufacture until the consumming industries were sufficiently developed to support units of economic size.

4. Nevertheless, since heavy chemicals are required either as raw material or essential auxiliaries by almost every manufacturing industry the general progress of industrial development results in an every increasing and sometimes alarming demand for these chemicals and there is a natural desire to see them produced locally at as early a stage as possible. This can be misleading.

5. The discrepancy in the standards of living between the less and the most fully developed areas does not necessarily call for immediate industrial development. Countries with surpluses of food or other "primary" products and raw materials have achieved quite a high standard of living by developing exports of these in exchange for manufactured goods. In considering the less well developed areas it is natural to think of the newer Afro-Asian nations but it is not so long since Canada, Australia and South Africa merited this description and parts of them still do so. It is well to remember that their development was founded, and their present prosperity still largely depends on, primary industry. The same would seem to apply to South America also but of this the author has no first hand knowledge.

6. Conversely, countries without such surpluses but with adequate supplies of the requisite raw materials and power may justify chemical manufacture at an earlier stage. The role of the chemical industry, its pattern and impact must depend on the peculiar circumstances of the area in question to a greater extent than is perhaps usually realised.

7. Generally, however, industry follows hard on the heels of primary production and sooner or later the stage is reached when (heavy) chemical manufacture warrants consideration. The potential saving on imports is attractive if not indeed, vital, but at once the high capital cost of modern chemical plants proves a most serious obstacle. Development generally, but particularly industrial development requires massive capital investment and as the availability of capital whether from internal savings or external aid (both ultimately arising from voluntary saving or taxation of individuals) is inevitably limited development must be keenly selective particularly in the early stages of industrialisation, and in this the chemical industry must compete with others. It is also not sufficiently realised that the technical resources and manpower available frequently impose an even more severe limitation. This is the justification for the considerable degree of planning which is accepted publicly and certainly desirable privately in developing countries, but there is insufficient unanimity on the criteria to be adopted and the limitations of the above factors. There are few countries indeed in which the various "plans" have been fully completed within the stated period and have fully achieved the postulated results.

8. National authorities inevitably tend to be concerned primarily with balance of payment problems and to plan development mainly on this basis. The private sector tends rather to make its judgements on purely economic conditions. The disposal or utilisation of profits is a matter of policy both public and private, but the making of the profit (in this context the savings as compared with the previous situation) provides the means both of raising the standard of living through distribution of purchasing power and of generating further capital for future expansion. Whatever the policy clearly profitability is the best "rough and ready" yardstick in deciding what will contribute most to the tempo of development and, although compromise may later have to be made, it should be used as the first criterion in selecting both fields of development and individual projects. It is against this background that the role of heavy chemicals must be determined.

9. Obviously any planning whether on the national or individual scale must start with an assessment of the area's growing needs against the evolving pattern of its general development. This presupposes some decisions regarding priorities for such development and emphasises the "tertiary" role of the chemical industry. At once the question of timing or in popular parlance the "minimum economic size" arises but, although figures are often glibly quoted for particular processes, this concept is by no means as simple as generally supposed. It will be considered more fully later.

10. The next consideration is usually the availability of raw materials. The full range of these for the heavy chemical industry is very large but the main bulk comprises a relatively few items such as air, water, salt, lime, sulphur, phosphates carbon, and especially hydrocarbons. Rarely are all of these conveniently available. Energy, either as fuel or electricity, might almost be classed as a raw material also, so great is the dependence of many of the more important processes upon its availability and cost.

11. The basic processes of the chemical industry start from these raw materials yielding products sometimes referred to as "primaries" and serving generally as the starting point for further processes. Because of this a high degree of inter-locking is inevitable in the heavy chemical industry if economic operation is to be achieved and wasteful transport of intermediates avoided.

12. This inter-locking has been demonstrated on innumerable occasions by elaborate charts and it is not proposed to repeat them here as they are readily accessible and no doubt familiar to the delegates but it may be useful to consider briefly the major sectors of the heavy chemical industry in some such order as they might merit attention in a developing country.

13. One chemical process arises naturally, namely fermentation. Many countries have large resources of saccharosic material from which ethanol and other fermentation products can be produced cheaply and it would seem that over the last few decades an opportunity to exploit these may have been missed. The development of petrochemical processes is putting ethanol and other fermentations out of court in the highly industrialised areas but in view of the relatively low capitalisation and given sufficiently cheap raw material ethanol, butanol, acetone, acetic and citric acids and even possibly glycerine may still be worth consideration by fermentation routes, particularly if oil is not available indigenously. More complex products can be produced but the separation and recovery proves extremely difficult. The advent of new techniques might produce spectacular results.

14. Probably the first heavy chemicals required will be fertilisers and the relative importance of nitrogen, phosporous and potash is under discussion in other sections of the conference. These products are produced very efficiently on a very large scale in the advanced countries and it will require a large local demand and/or favourable circumstances to permit competitive manufacture but some premium may be considered justifiable to save foreign exchange. Nitrogen in the form of synthetic ammonia is generally the easiest to justify and for the traditional (and still generally preferred) product ammonium sulphate, anhydrite or gypsum

can be used rather than sulphuric acid which usually involves imports of sulphur. In certain countries work on the beneficiation of gypsum/anhydrite might be rewarding. The newer ammonium nitrate based products are attracting much attention. The newer processes for synthesis gas, based on naptha etc., have probably reduced the minimum economic size of plant as well as avoiding dependence on the all too scarce supplies of metallurgical coke.

15. Phosphate fertilisers pose a more difficult problem since in general import of rock phosphate and sulphur are involved. Only in very rare circumstances can production via elemental phosphorous be justified. Potash products are almost inevitably tied to the source of the mineral.

16. Consideration of fertilisers naturally leads on to acids. Sulphuric plants are now available virtually as package units where required but the availability of synthetic ammonia with possibly methanol as a side-line opens the way to nitric acid, and hence explosives, organic nitrations etc., as well as aminations etc.,

17. Explosives are a small but highly specialised field. It is easy to produce explosive compositions, as the bones of many men testify but the production of cheap safe efficient and reliable products involves a very special technology to which much research has been devoted. The recent trend towards crude on-site mixtures of ammonium nitrate (which still require to be initiated and boosted by sophisticated explosives) appears to be reversing. (1)

18. One product which because of its high transport cost can frequently be manufactured on relatively small scale is chlorine but only for such essential applications as public hygiene, water purification etc., For general industrial use, the woodpulp industry and particularly the plastics field and more complex chlorinated products, large units, say 20,000 tons and upwards, and cheap salt and power are essential.

19. Production of chlorine yields a useful bonus of caustic soda and indeed the demand for this usually surpasses that for chlorine until a very high level of industrialised development is achieved. This focuses attention on the soda ash process and caustic therefrom. Unfortunately the ammonia -soda process demands a very high degree of technical skill and large units; outputs of 200 tons per day being regarded as quite small. It is also all too often difficult to find satisfactory supplies of salt, lime and make-up ammonia as well as fuel within reach. The so called combined process obviates the lime difficulty but requires large supplies of ammonia and an outlet for the ammonium chloride which is separated. It is by no means as well established as the orthodox process.

(1) Damon G.H., Low-Cost Blasting Agents
J.Mines, Metals & Fuels. Special Issue
(1962) P.305

20. The availability of these fundamental chemicals opens the way to consideration of a great multitude of possible manufactures. On the inorganic side these are mainly salts of varying complexity with perhaps special mention of silicates and inorganic pigments. All of these involve specialised processes and it is impossible to generalise as to their practicability in newly developing areas. Opportunities may arise however, not merely of supplying local demand but of up-grading or semi-processing raw materials formerly exported in the crude state.

21. On the organic side the proliferation is even greater. Till recently the organic raw materials were largely derived from coal with the addition of acetylene, synthetic methanol, the simpler parrafin fractions and natural substances such as cellulose, rubber, oils and wares etc., The possible sulphonations, nitrations, chlorinations, aminations, oxidations, reductions hydroxylations etc., of these and all their permutations and combinations filled the technical literature as well as the warehouses. These units processes, if the raw materials and reagents are available can often be economic on a relatively small scale.

22. Stemming from the oil industry and influenced by its most modern technology, the new field of petrochemicals has developed over the last twenty years deriving a wide range of aliphatic and aromatic chemicals from cheap (naphtha) fractions of petroleum. The initial impetus in this field seems to have been derived from the very large scale production of butadiene, styrene and synthetic rubber during the war and has been sustained by the phenomenal post-war development of polythene and other synthetics. It has branched out into a wide variety of chemicals but the processes generally exhibit a high degree of sophistication and being essentially continuous can only be operated economically on quite large scale. For the initial operation a cracker handling of say 200,000 tons of naphtha per annum is usually regarded as fairly small though admittedly crackers of less than half this size have been considered. An integrated complex of many processes is required for the economic utilisation of the many products of such crackers and unfortunately not many of the less developed areas can envisage sufficient demand in the foreseeable future to justify such massive investment.

23. Stripped of its superficial glamour the plastics field is seen to consist of a highly competitive fabricating industry utilising the products of highly developed capital intensive processes. The earlier thermo-setting resins could be produced in relatively simple plant but increasingly stringent specifications demand greater control and complication in the process. The newer plastics are all products of high cost plants and processes. It is proving difficult therefore to produce any of these economically in small units.

24. In the synthetic or artificial fibre field it may not be too difficult to supply local needs of rayon or other cellulose fibre given adequate supplies of cellulose, caustic and other reagents at economic prices, but it must be remembered that the more economic producers operate units of capacity up to 100,000 tons per annum. It is also possible to establish spinning of the true synthetic fibres, polyamide, polyester and acrylics on relatively small scale if importation of polymer or at least advanced intermediates is accepted but complete synthesis will usually demand annual tonnages running into five figures before competitive costs can be approached. All these processes make heavy demands on technically skilled manpower.

25. Reference must be made to the dyestuffs industry which constitutes the main exception to the rule of specialised one-product plants. In view of the literally thousands of dyestuffs and intermediates to be produced much ingenuity is devoted to devising multi-purpose units. Nevertheless, the trend is still evident and most of the primary and many of the intermediate chemicals are now produced by such specialised processes. This is a field in which research and invention play, if possible, a greater part than in any other with a proliferation of patents and constant supplanting of one product or process by a newer one. It is worth noting that no country is entirely self-sufficient in this field and the world situation is confused by the fact that availability even of intermediates varies greatly from time to time according to consumer fashion and level of demand in the various countries. The planning of a dyestuffs unit in a new country is particularly difficult and indeed the economics of producing individual dyes and intermediates are often nearly impossible to asses. In such a field a policy of backwards development is almost inevitable starting with the end product and working back to the primary material as the industry grows. Similar considerations apply also to the multitude of other organic products which have been developed as offshoots of the dyestuffs industry.

26. Reference has already been made to the high cost of modern chemical plants and the influence of the size factor on their economics and been discussed interalia by Chiltern (2), Dickerson (3) and Johnstone (4). It is usual to consider cost as an exponential function of size but the exponent can vary widely and may be as low as 0.5 if the capacity is changed by variation in the unit size of the items of equipment or as high as 0.9 where expansion implies a number of units working in parallel. Neglecting the extreme cases, it is customary to consider the cost of the plant and equipment as varying by about the 0.6th power of the capacity. Such an exponential function obviously implies a serious initial disadvantage in the less developed areas since despite their generally large population, demand even within the next five to ten years will usually be only a fraction o the accepted size elsewhere. It is an interesting observation that in many sectors of the heavy chemical industry the demand in India is of the same order as that in Australia despite the enormous disparity in the respective populations (dyestuffs and soda ash are major exceptions; for obvious reasons)

(2) Chilton, C.H. Chem. Eng. 57 112-114 (April 1950)
(3) Dickerson, R.G. Inst. Chem. Eng. Joint Symposium on Scaling-up (1957)
(4) Johnstone, R.Edgeworth. Trans Inst. Chem. Eng. 32 151-166 (1954)

27. The planner of a heavy chemical unit is therefore often faced with a prospective unit possibly as small as one fifth of the normally accepted size and costing therefore perhaps twice as much per ton-year on account of the scale factor alone. Added to this must of the equipment will be highly specialised and therefore have to be imported involving substantial charges for packing, insurance, freight etc., which may increase the capital cost by, say, a further 25%. In the light of this the levying import duty on imported capital equipment is hard to understand.

28. In addition to this handicap the cost of services plant, laboratories, offices and other ancillaries will generally be much higher pro rata than in the industrially developed regions. In some countries, moreover, it may be necessary to spend perhaps as much as 20% of the total cost of the project on housing and other amenities which elsewhere already exist or are provided independently. All of these factors affect not merely the capital but also the productions costs, as well as the margin of profit required either to service the capital or to justify the projects as already discussed.

29. On the other hand, the other factors affecting production costs are not necessarily so unfavourable. Services may well be obtainable at figures comparable with those in the highly developed countries while the problem of low productivity of local labour has perhaps been over-stressed. No doubt this is being adequately discussed in other sections of the Conference, and it suffices to say that in the author's experience in the heavy chemical industry, quite surprising results have been obtained through the thorough application of work study at the design stage and in "manning-up" together with the fullest training of both supervisory and operating personnel well in advance of starting up new plants.

30. By and large therefore the greatest obstacle to the establishment of the heavy chemical industry in new areas is the increasing sophistication of the processes and the consequent high unit cost of plants which because of the scale factor strongly favours the installation of large units. The mounting bill for heavy chemicals to support general industrial development encourages the establishment of small units at the earliest possible moment but this tendency must be resisted otherwise the prospect must be faced of scrapping them in favour of more economic units at an early date. From consideration of the cost-v-scale factor it is also obvious that economic operation cannot be achieved by the successive installation of uneconomic units operating in parallel. For the same reasons however attractive dispersion of the chemical industry may be politically, fragmentation into uneconomic units can only frustrate the objects of industrial development.

31. The prospect however is not entirely gloomy and in particular the concept of minimum economic size is very arbitrary and depends greatly on local circumstances. It is simply the scale of operation at which an acceptable return or saving is secured with local costs and at obtainable or acceptable price levels. The results of such appraisals may represent

different orders of magnitude in different areas. It is important to realise that in such cases careful re-study of the process from both the technological and chemical engineering aspects will often produce rewarding results. On a smaller scale unit operations can sometimes be combined or the process simplified in other ways. Handling problems are often simplified and where ample low cost labour is available manual handling may even produce substantial savings in both capital and operating costs as well as creating additional employment. It is disturbing at times to see highly expensive equipment installed without any attempt to determine whether its cost is as well justified as in the areas of high cost labour where it was developed. It is always possible to allow for its installation later if and when the increasing standard of living have raised wages to the critical level. In any case climatic conditions and other local conditions such as variations in material specifications and costs usually justify a technological re-assessment or re-interpretation of the process and too much skill and ingenuity cannot be devoted to the problem of reducing capital costs and increasing efficiency. This may also achieve substantial savings in the foreign exchange required to import plant and equipment.

32. Summing up therefore heavy chemicals are the servants of industry generally and the demand for them will grow with increasing industrialisation. As most developing areas are faced with exchange problems the mounting bill will result in pressure to manufacture them locally but since capital is also scarce such manufacture should only be contemplated in well planned units of adequate size. It should also be accepted that integrated manufacturing complexes must be built up to achieve normal efficiencies. Location must be decided strictly on economic considerations having regard to distribution of demand, raw materials, and cost of transport etc., and the timing of projects and their mutual interlocking and support is of prime importance. The marginal gain each year in the struggle towards the so-called "self generating stage" is usually quite small and if political dogma or expediency be allowed to distort sound techno-economic planning the overall objective of industrial and all development will be vitiated. On the other hand, ample technical skill and experience should be devoted to adapting processes and plant to local conditions so as to secure maximum efficiency, reduce capital cost and secure the maximum return on savings.

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